

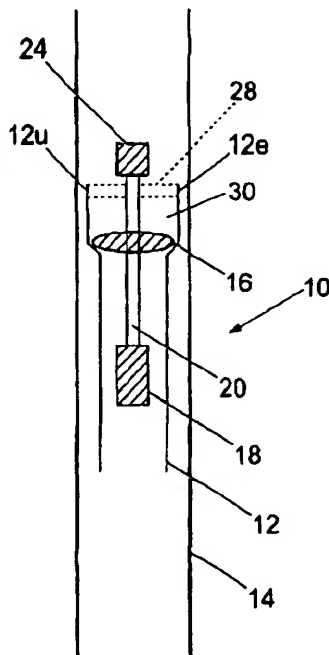
## (12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau(43) International Publication Date  
14 November 2002 (14.11.2002)

PCT

(10) International Publication Number  
**WO 02/090713 A1**

- (51) International Patent Classification<sup>7</sup>: **E21B 43/10, 4/00** (74) Agent: **MURGITROYD & COMPANY**; 165-169 Scotland Street, Glasgow G5 8PL (GB).
- (21) International Application Number: **PCT/GB02/02171**
- (22) International Filing Date: **9 May 2002 (09.05.2002)**
- (25) Filing Language: **English**
- (26) Publication Language: **English**
- (30) Priority Data:  
0111413.1 **9 May 2001 (09.05.2001)** **GB**
- (71) Applicant (for all designated States except US): **e2 TECH LIMITED** [GB/NL]; Shell International B.V., P.O. Box 384, NL-2501 CJ The Hague (NL).
- (81) Designated States (national): **AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.**
- (84) Designated States (regional): **ARIPO** patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), **Eurasian** patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), **European** patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), **OAPI** patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): **BURGE, Philip, Michael** [GB/GB]; Blackchambers, Westhill, Aberdeenshire AB32 7BU (GB). **DOBSON, Andrew, Warnock** [GB/GB]; 37 Kirk Crescent, North Cults, Aberdeen AB15 9RP (GB).
- Published:  
— with international search report
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: **APPARATUS FOR AND METHOD OF RADIAL EXPANSION OF A TUBULAR MEMBER**

(57) Abstract: Apparatus for and method of radial expansion of a tubular member, with embodiments of the apparatus including an expander device (16), for example an expansion cone, which has a drive means (18) either attached to it or integral therewith. The drive means (18) can be a pump for example, where the pump creates a differential pressure across the expander device (16) to cause it to move.

1     "Apparatus for and Method of Radial Expansion of a  
2     Tubular Member"

3  
4     The present invention relates to apparatus and a  
5     method particularly for the radial expansion of  
6     tubular members.

7  
8     Conventionally, tubular members can be expanded using  
9     mechanical or other devices and methods where an  
10    expander device (e.g. a cone) is pushed or pulled  
11    through the tubular member to impart a radial plastic  
12    and/or elastic deformation to the member to increase  
13    its outer diameter (OD) and inner diameter (ID).  
14    Alternatively, the cone may be forced through the  
15    tubular member using hydraulic pressure. The tubular  
16    member is optionally at least temporarily anchored  
17    and the expander device is pushed or pulled through  
18    the tubular member to impart the radial expansion  
19    force.

20  
21    There are a number of problems associated with so-  
22    called "bottom-up" expansion. The portions of the

1 tubular member that have been expanded below the cone  
2 may be in tension or compression during the expansion  
3 process depending upon the location of the temporary  
4 anchor (where used). Thus, during hydraulic  
5 expansion of the tubular member for example, the  
6 member is in a state of tension while also under  
7 hydraulic pressure. Also, in the event of problems  
8 with the expansion, the cone can potentially become  
9 stuck as it is being pushed or pulled through the  
10 expandable member, and this may require a fishing  
11 operation to retrieve the stuck cone.

12

13 Additionally, conventional methods typically require  
14 a rig so that the expander device can be pushed or  
15 pulled through the tubular member using a wireline,  
16 drill string, coiled tubing string or the like.

17

18 According to a first aspect of the present invention,  
19 there is provided apparatus for radially expanding a  
20 tubular member, the apparatus comprising an expander  
21 device and a drive means for the expander device, the  
22 drive means being capable of moving with the expander  
23 device.

24

25 According to a second aspect of the present  
26 invention, there is provided apparatus for radially  
27 expanding a tubular member, the apparatus comprising  
28 an expander device and a drive means for the expander  
29 device, the drive means being capable of entering the  
30 tubular member and moving the expander device.

1 According to a third aspect of the present invention,  
2 there is provided a method of radially expanding a  
3 tubular member, the method comprising the steps of  
4 providing an expander device and a drive means,  
5 locating the device and drive means in the tubular  
6 member, and actuating the drive means to radially  
7 expand the member.

8  
9 The invention also provides apparatus for expanding a  
10 tubular member, comprising an expander device having  
11 an integral drive means for moving the device within  
12 the tubular member.

13  
14 The expander device is preferably an expansion cone.

15  
16 The drive means typically comprises a pump. The pump  
17 is typically attached to the expansion cone (e.g. by  
18 a shaft or the like) but can be integral therewith.  
19 For example, the expansion cone can be provided with  
20 a longitudinal throughbore in which the pump can be  
21 located.

22  
23 The pump is typically used to create a differential  
24 pressure across the expansion cone. The differential  
25 pressure across the cone typically causes it to move  
26 towards an area of lower pressure. The pump  
27 typically draws fluid from one side of the expansion  
28 cone to the other, thus causing the area of lower  
29 pressure. The pump can be of any conventional type,  
30 and can be, for example electric- or hydraulic-  
31 driven. This has the advantage that only an electric

1 cable is required from the surface, and in certain  
2 embodiments this is not required (e.g. where the pump  
3 is hydraulically-driven). Where the pump is  
4 electric-driven, no rig or the like is generally  
5 required to push or pull the expander device.

6  
7 A turbine can be used to provide power for the pump.  
8 The turbine is typically fluid-driven (e.g.  
9 hydraulically-driven).

10  
11 The tubular member is optionally at least temporarily  
12 anchored at an end thereof at least during radial  
13 expansion of the member. A mechanical slip or packer  
14 can be used as an anchor.

15  
16 The tubular member is typically located in a second  
17 conduit before radial expansion. The second conduit  
18 may comprise a borehole, casing, liner or other  
19 downhole tubular.

20  
21 The tubular member can be any downhole tubular that  
22 is capable of plastic and/or elastic deformation.  
23 The tubular member is typically of steel or a steel  
24 alloy (e.g. nickel alloy). The tubular member is  
25 typically of a ductile material.

26  
27 The tubular member can be a discrete length of  
28 downhole tubular, or can be a string of downhole  
29 tubulars that are coupled together (e.g. by welding,  
30 screw threads etc).

31

1 The expansion cone can be of any conventional type.  
2 The expansion cone is typically of a material that is  
3 harder than the tubular member that is has to expand.  
4 The expansion cone may be of ceramic, steel, steel  
5 alloy, tungsten carbide or a combination of these  
6 materials. It will be noted that only the portions  
7 of the expansion cone that come into contact with the  
8 tubular to be expanded need be coated or otherwise  
9 covered with the harder material.

10  
11 The method typically includes the additional step of  
12 locating the tubular member in a second conduit.

13  
14 The method optionally includes the additional step of  
15 temporarily anchoring an end of the tubular member.

16  
17 The step of actuating the drive means typically  
18 comprises applying power to the pump. Alternatively,  
19 the step of actuating the drive means may comprise  
20 applying power to the turbine.

21  
22 Embodiments of the present invention shall now be  
23 described, by way of example only, with reference to  
24 the accompanying drawings in which:-

25 Fig. 1 is a schematic representation of an  
26 embodiment of apparatus that is being run into a  
27 casing;

28 Fig. 2 is a schematic representation of the  
29 apparatus of Fig. 1 in use;

30 Fig. 3a is a front elevation showing a first  
31 configuration of a friction and/or sealing

1 material that can be applied to an outer surface  
2 of a tubular;  
3 Fig. 3b is an end elevation of the friction  
4 and/or sealing material of Fig. 3a;  
5 Fig. 3c is an enlarged view of a portion of the  
6 material of Figs 3a and 3b showing a profiled  
7 outer surface;  
8 Fig. 4a is an front elevation of an alternative  
9 configuration of a friction and/or sealing  
10 material;  
11 Fig. 4b is an end elevation of the friction  
12 and/or sealing material of Fig. 4a; and  
13 Fig. 5 shows an alternative embodiment of  
14 apparatus for radial expansion of a tubular  
15 member.

16  
17 Referring to the drawings, Fig. 1 shows an exemplary  
18 embodiment of apparatus 10 for the expansion of a  
19 tubular member. Apparatus 10 as shown in Fig. 1 is  
20 typically located within a portion of a downhole  
21 tubular member 12 that is to be radially expanded  
22 within a pre-installed portion of casing 14. The  
23 tubular member 12 can be any downhole tubular such as  
24 a casing, liner or the like and is typically of a  
25 ductile material that is capable of plastic and/or  
26 elastic deformation. The tubular 12 is typically of  
27 steel or an alloy of steel (e.g. nickel alloy), but  
28 other materials may be used. The pre-installed  
29 casing 14 may be any conventional downhole tubular  
30 such as casing, liner, drill pipe etc, and indeed

1     could be an open borehole that is to be cased and/or  
2     lined.

3

4     Apparatus 10 includes an expansion cone 16 that is  
5     typically located in a pre-expanded portion 12e of  
6     the tubular 12 as the apparatus 10 is run in. The  
7     expansion cone 16 has a pump 18 attached thereto e.g.  
8     by a shaft 20. Expansion cone 16 may be of any  
9     conventional type, but is typically of a material  
10    that is harder than the material of the tubular  
11    member that it has to expand. The cone 16 can be,  
12    for example, of ceramic, steel, a steel alloy or  
13    tungsten carbide etc. It may only be necessary to  
14    coat or otherwise cover the portions of the cone 16  
15    that come into contact with the tubular 12 during  
16    expansion with a harder material.

17

18    Apparatus 10 is typically located within the tubular  
19    12 at the surface. In particular, the expansion cone  
20    16 is typically located within the pre-expanded  
21    portion 12e of the tubular 12 at the surface.  
22    Thereafter, the apparatus 10 and the tubular 12 are  
23    run into the borehole to the position within casing  
24    14 at which the tubular 12 is to be radially  
25    expanded.

26

27    The pump 18 can be of any conventional type, e.g.  
28    electrically- or hydraulically-driven. It will be  
29    appreciated that the pump 18 may be incorporated  
30    within the expansion cone 16 itself. For example,  
31    and with reference to Fig. 5 showing an alternative



1     embodiment of apparatus 200, the cone 216 can be  
2     provided with a throughbore 217 in which the pump 218  
3     can be located. This would be particularly  
4     advantageous as the apparatus 200 can be made smaller  
5     and more compact.

6  
7     The pump 18 is typically an electrical submersible  
8     pump (ESP) that includes a pump driven by an electric  
9     motor. Thus, an electrical cable (not shown) is  
10    typically provided from the surface and coupled to  
11    the motor of the pump 18 to drive it. Having the  
12    pump 18 driven by electricity has advantages in that  
13    only the electrical cable from the surface is  
14    required. Thus, a rig or the like is not generally  
15    required and the operation of the apparatus 10 can be  
16    autonomous in that very little user intervention, if  
17    any, is required.

18  
19    The electrical cable can form part of an umbilical  
20    cable or wireline that can be attached to apparatus  
21    10. The umbilical or wireline has advantages in that  
22    the apparatus 10 can be more easily retrieved from  
23    the borehole once the tubular 12 has been radially  
24    expanded, or if the apparatus 10 becomes stuck due to  
25    a protrusion or restriction in its path.

26  
27    Alternatively, the pump 18 can be driven by a turbine  
28    24 that is typically located above the cone 16. The  
29    turbine 24 is typically hydraulically-driven, and the  
30    apparatus 10 is typically attached to a coiled tubing  
31    string, drill string or the like through which fluids

1 may be pumped to drive the turbine 24. This would  
2 generally require the use of a rig and may be useful  
3 where a rig is already in place and available.

4  
5 Although the turbine 24 has been shown in Figs 1 and  
6 2, it will be appreciated that it will not be  
7 required where the pump 18 is electrically-driven;  
8 all that will be required is a power cable to the  
9 motor of the pump 18.

10  
11 The purpose of the pump 18 is to draw fluids from  
12 below to above the cone 16 (as indicated by arrow 22  
13 in Fig. 2), thereby creating a pressure differential  
14 across the cone 16, which causes the cone 16 to move  
15 downwards through the tubular 12, thus deforming and  
16 radially expanding it. This is because the pump 18  
17 creates an area of high pressure above the cone 16  
18 and an area of lower pressure below it. Thus, the  
19 cone 16 will be moved by the pressure differential  
20 across it.

21  
22 The pump 18 is typically mounted at a short distance  
23 below the cone 16. The shaft 20 typically comprises  
24 of two concentric conduits. An inner conduit (not  
25 shown) would either house the drive shaft from the  
26 turbine 24 to the pump 18; carry hydraulic fluid from  
27 the surface (through a suitable string) to the  
28 turbine where it is mounted below the cone 16 and  
29 adjacent the pump 18; or to carry the electric cable  
30 26 to take power to the pump 18. An outer conduit is  
31 typically used as a conduit for the pressurised fluid

1 that is pumped from below the cone 16 to above it.  
2 One or more ports would be provided in the cone 16 at  
3 the termination of the outer conduit to allow fluid  
4 to be pumped above the cone 16.

5  
6 The radial expansion of the tubular 12 typically  
7 causes an outer surface thereof to contact an inner  
8 surface of the pre-installed casing 14, but this is  
9 not essential. For example, the outer surface of the  
10 tubular 12 can be provided with a friction and/or  
11 sealing material to provide an anchor and seal in the  
12 annulus between the tubular 12 and the casing 14.  
13 Alternatively, spacers may be located in the annulus  
14 or cement used.

15  
16 Use of the terms "above", "below", "upward" and  
17 "downward" herein are used with respect to the  
18 orientation of the apparatus shown in Figs 1 and 2.  
19 These terms should be construed accordingly where the  
20 apparatus is used in a lateral or deviated borehole.  
21 The terms "below" and "downward" generally refer to  
22 locations or directions that are nearer the formation  
23 or payzone.

24  
25 It will be appreciated that the apparatus 10 can be  
26 used to expand the tubular 12 from the bottom-up by  
27 reversing the direction of the apparatus 10 (e.g.  
28 turning it upside down with respect to the  
29 orientation of the apparatus in Fig. 1). However, it  
30 is advantageous to use the apparatus 10 to expand the  
31 tubular 12 from the top-down because the apparatus 10

1 can be retrieved easily and more quickly should its  
2 travel be arrested due to a protrusion or restriction  
3 in its path. This is because the portions of the  
4 tubular 12 that have not been expanded when the  
5 apparatus 10 becomes stuck will be below the  
6 apparatus 10, and thus it can be pulled out of the  
7 borehole relatively easily.

8  
9 The cone 16 is typically located in the pre-expanded  
10 portion 12e as tubular 12 is lowered into the  
11 borehole, as shown in Fig. 1.

12  
13 The cone 16 can be attached to a drill string, coiled  
14 tubing string or the like, but this is not generally  
15 required, as the pump 18 can be electric so that only  
16 an electrical cable to the pump 18 is required.  
17 Alternatively, the pump 18 may be hydraulically-  
18 driven and this generally requires a drill string or  
19 coiled tubing string for example through which fluids  
20 may be pumped (e.g. from the surface) to drive the  
21 pump 18 downhole.

22  
23 The expansion process can therefore be autonomous  
24 where an electric pump and cable are used; that is  
25 once the pump 18 is actuated, there need be no  
26 further user intervention until the apparatus 10 is  
27 to be retrieved from the borehole (e.g. using a  
28 conventional fishing operation). However, a wireline  
29 or umbilical may be attached to the apparatus 10 to  
30 facilitate easy retrieval from the borehole should it  
31 become stuck, or once it has expanded the tubular 12.

1

2 Also, where the pump 18 is electrically-driven, no  
3 rig is required because a wireline, coiled tubing  
4 string or drill string is not required to propel the  
5 apparatus 10; only an electrical cable is required.  
6 This has significant advantages because the apparatus  
7 10 can be used to repair damaged or washed-out liner  
8 by overlaying another liner on top and radially  
9 expanding this into place so that it straddles the  
10 damaged portion, without the need to use a rig. The  
11 apparatus 10 can also be used to install new casing,  
12 liner etc without the need for a rig.

13

14 The tubular 12 is optionally at least temporarily  
15 anchored at an end thereof during the expansion  
16 process. The tubular 12 can be anchored using any  
17 conventional means, such as a mechanical slip or a  
18 packer for example. Where the anchor is located at a  
19 lower end of the tubular 12, and expansion begins at  
20 the lower end, the tubular 12 will generally be in  
21 tension during the expansion process. This is also  
22 the case where the tubular 12 is anchored at the top  
23 and the expansion process is top-down. Where the  
24 anchor is located at an upper end of the tubular 12  
25 and the expansion process is bottom-up, the tubular  
26 12 will generally be in compression during the  
27 expansion process. Similarly, if the tubular 12 is  
28 anchored at a lower end and the expansion process is  
29 top-down, the tubular 12 will generally be in  
30 compression during expansion.

31

1 In certain embodiments, the apparatus 10 can include  
2 an inflatable device 28 (e.g. a packer) that is  
3 shown in phantom in Figs 1 and 2. The inflatable  
4 device 28 can be located in the pre-expanded portion  
5 12e and then inflated at the required depth to  
6 provide a temporary anchor for the tubular 12 to the  
7 pre-installed casing 14. The inflatable device 28  
8 can be releasably attached to the apparatus 10 so  
9 that once it has formed an anchor, it can be detached  
10 from the apparatus 10 and left *in situ* to be  
11 collected once the expansion process is completed  
12 (e.g. as the apparatus 10 is pulled out of hole).  
13 The inflation of the inflatable device 28 causes the  
14 pre-expanded portion 12e to be expanded further so  
15 that a portion thereof contacts the casing 14.  
16 Alternatively, or additionally, an outer surface of  
17 the tubular 12 can be provided with a friction and/or  
18 sealing material (e.g. rubber) that engages the  
19 casing 14 to provide a seal there between, and also  
20 to provide an anchor point for the subsequent  
21 expansion of the tubular 12.

22  
23 The inflatable device 28 can also be used to provide  
24 a fluid chamber 30 in which fluid that is pumped from  
25 below the cone 16 can collect. The build up of  
26 pressure in the chamber 30 and the lower pressure  
27 below the cone 16 causes the cone 16 to move  
28 downwards and thus expand the tubular. The  
29 inflatable device 28 provides a local seal for the  
30 fluid pressure above the cone 16 and would generally  
31 only be required until a sufficient portion of the

1 tubular 12 has been expanded to provide a seal. The  
2 seal can be created by a metal-to-metal contact  
3 between the tubular 12 and the casing 14, but a  
4 friction and/or sealing material can be provided on  
5 the outer surface of the tubular 12 so that a seal is  
6 created when the tubular 12 is expanded. Once the  
7 tubular 12 has been expanded sufficiently to provide  
8 a seal, the inflatable device 28 is generally no  
9 longer required and can be deflated.

10  
11 Where the inflatable device 28 is located within the  
12 pre-expanded portion 12e, as shown in Fig. 1, the  
13 inflatable device 28 can be used to expand the pre-  
14 expanded portion 12e (or portions thereof), as  
15 described above. The pre-expanded portion 12e can be  
16 provided with the friction and/or sealing material so  
17 that the material is energised upon inflation of the  
18 inflatable device to provide a local seal for the  
19 fluid pressure.

20  
21 The inflatable device 28 can be telescopically  
22 attached to the expansion cone 16, and may be of any  
23 suitable configuration, but is typically a device  
24 that has an inflatable annular balloon-type portion  
25 that is mounted on an annular ring. The annular ring  
26 allows a string, wireline or the like to be passed  
27 through the inflatable device 28 as required, or in  
28 the embodiment shown, allows the shaft 20 and the  
29 electrical cable to the pump 18 (if required) to pass  
30 therethrough.

31

1 Where the expansion cone 16 is telescopically coupled  
2 to the inflatable device 28 using a telescopic  
3 coupling, the coupling typically comprises one or  
4 more telescopically coupled members that are attached  
5 to the inflatable device 28. As the expansion cone  
6 28 moves downwards, the telescopic coupling extends a  
7 certain distance, say 10 feet (approximately 3  
8 metres), at which point the telescopic member(s) are  
9 fully extended. At this point, the inflatable  
10 balloon-type portion of the inflatable device can be  
11 automatically deflated and further downward movement  
12 of the expansion cone 16 causes the inflatable device  
13 28 also to move downward therewith.

14  
15 It should be noted that the inflatable device 28 is  
16 no longer required to anchor the tubular 12 to the  
17 casing 14 as the expanded portion of tubular 12  
18 secures it to the casing 14. A friction and/or  
19 sealing material (e.g. material 100, 122 as described  
20 below) can be used to enhance the grip of the tubular  
21 12 on the casing 14 in use, and can also provide a  
22 seal in an annulus created between the tubular 12 and  
23 the casing 14.

24  
25 Referring to Figs 3a to 3c, there is shown an  
26 exemplary configuration of a friction and/or sealing  
27 material 100 that can be applied to the outer surface  
28 of the tubular 12. The material 100 typically  
29 comprises first and second bands 102, 104 that are  
30 axially spaced-apart along a longitudinal axis of the  
31 tubular 12. The first and second bands 102, 104 are



1 typically axially spaced by some distance, for  
2 example 5 inches (approximately 127mm).

3  
4 The first and second bands 102, 104 are preferably  
5 annular bands that extend circumferentially around  
6 the tubular 12, although this configuration is not  
7 essential. The first and second bands 102, 104  
8 typically comprise 1 inch wide (approximately 25.4mm)  
9 bands of a first type of rubber. The friction and/or  
10 sealing material 100 need not extend around the full  
11 circumference of the tubular 12.

12  
13 Located between the first and second bands 102, 104  
14 is a third band 106 of a second type of rubber. The  
15 third band 106 preferably extends between the first  
16 and second bands 102, 104 and is thus typically 3  
17 inches (approximately 76mm) wide.

18  
19 The first and second bands 102, 104 are typically of  
20 a first depth. The third band 106 is typically of a  
21 second depth. The first depth is optionally larger  
22 than the second depth, although they can be the same,  
23 as shown in Fig. 3a. The first and second bands 102,  
24 104 may protrude further from the surface of the  
25 tubular 12 than the third band 106, although this is  
26 not essential.

27  
28 The first type of rubber (i.e. first and second bands  
29 102, 104) is preferably of a harder consistency than  
30 the second type of rubber (i.e. third band 106). The  
31 first type of rubber is typically 90 durometer

1 rubber, whereas the second type of rubber is  
2 typically 60 durometer rubber. Durometer is a  
3 conventional hardness scale for rubber.

4

5 The particular properties of the rubber may be of any  
6 suitable type and the hardnessess quoted are  
7 exemplary only. It should also be noted that the  
8 relative dimensions and spacings of the first, second  
9 and third bands 102, 104, 106 are exemplary only and  
10 may be of any suitable dimensions and spacing.

11

12 As can be seen from Fig. 3c in particular, an outer  
13 face 106s of the third band 106 can be profiled. The  
14 outer face 106s is ribbed to enhance the grip of the  
15 third band 106 on an inner face 12i of the casing 12.  
16 It will be appreciated that an outer surface on the  
17 first and second bands 102, 104 may also be profiled  
18 (e.g. ribbed). The material of the third band 106  
19 can deform into the spaces between the ribs when it  
20 is compressed during expansion.

21

22 The two outer bands 102, 104 being of a harder rubber  
23 provide a relatively high temperature seal and a  
24 back-up seal to the relatively softer rubber of the  
25 third band 106. The third band 106 typically  
26 provides a lower temperature seal.

27

28 A number of portions 108 are provided in the first  
29 and second bands 102, 104. The portions 108 are of a  
30 reduced thickness in the lateral direction. The  
31 rubber of the first and second bands 102, 104 is

---

1 relatively hard and thus tends not to stretch. The  
2 portions 108 of reduced thickness allow the material  
3 to stretch at these portions without breaking.

4  
5 An alternative embodiment of a friction and/or  
6 sealing material 122 that can be applied to the outer  
7 surface of the tubular 12 is best shown in Figs 4a  
8 and 4b. The friction and/or sealing material 122 is  
9 in the form of a zigzag. In this embodiment, the  
10 friction and/or sealing material 122 comprises a  
11 single (preferably annular) band of rubber that is,  
12 for example, of 90 durometers hardness and is about  
13 2.5 inches (approximately 28mm) wide by around 0.12  
14 inches (approximately 3mm) deep.

15  
16 To provide a zigzag pattern and hence increase the  
17 strength of the grip and/or seal that the material  
18 122 provides in use, a number of slots 124a, 124b  
19 (e.g. 20) are milled into the band of rubber. The  
20 slots 124a, 124b are typically in the order of 0.2  
21 inches (approximately 5mm) wide by around 2 inches  
22 (approximately 50mm) long.

23  
24 To create the zigzag pattern, the slots 124a are  
25 milled at around 20 circumferentially spaced-apart  
26 locations, with around 18° between each along one  
27 edge 122a of the band. The process is then repeated  
28 by milling another 20 slots 124b on the other side  
29 122b of the band, the slots 124b on side 122b being  
30 circumferentially offset by 9° from the slots 124a on  
31 the other side 122a.

1  
2 As an alternative to having the inflatable device 28  
3 telescopically coupled to the expansion cone, the  
4 tubular 12 can be provided with an expandable portion  
5 of casing or liner (not shown). The expandable  
6 portion may be located at an upper end 12u of the  
7 tubular 12 or may be integral therewith.

8  
9 The inflatable device 28 is inflated to expand the  
10 inflatable annular balloon-type portion. As the  
11 balloon-type portion expands, the expandable portion  
12 of the tubular 12 also expands. The contact between  
13 the expandable portion and the casing 14 provides an  
14 anchor point and/or a seal between the tubular 12 (to  
15 which the expandable portion is attached or integral  
16 therewith) and the casing 14. Thus, the contact  
17 provides a seal for the fluid pressure that is used  
18 to force the expansion cone 16 through the tubular  
19 12.

20  
21 As the expansion cone 16 moves downward through the  
22 tubular 12 to radially expand it, the movement of the  
23 cone 16 is stopped after a predetermined time or  
24 distance, at which point the cone 16 can be retracted  
25 until a coupling between the expansion cone 16 and  
26 the inflatable device 28 latches. At this time, the  
27 inflatable annular balloon-type portion is  
28 automatically deflated and the apparatus 10 is  
29 actuated and begins to move downward. Movement of  
30 the expansion cone 16 causes the inflatable device 28  
31 also to move downward. It should be noted that the

1 downward movement of the expander device 16 should  
2 only be stopped once a sufficient length of tubular  
3 12 has been expanded to provide a sufficient anchor.  
4

5 It should also be noted that the expandable portion  
6 is no longer required to anchor the tubular 12 to the  
7 borehole as the portions of the tubular 12 that have  
8 been expanded by movement of the apparatus 10 secures  
9 the tubular 12 to the casing 14. The friction and/or  
10 sealing material (where used) can help to provide a  
11 reliable anchor for the tubular 12 whilst it is being  
12 expanded and also when in use.  
13

14 As a further alternative, the inflatable device 28  
15 can be releasably attached to the upper end 12u of  
16 the tubular 12 before the apparatus 10 is run into  
17 the borehole. The expansion cone 16 is located  
18 within the upper end 12u of the tubular 12, the upper  
19 end 12u being pre-expanded to accommodate the  
20 expansion cone 16. Similar to the previous  
21 embodiment, the inflatable device 28 has the  
22 expansion cone 16 releasably coupled thereto via a  
23 suitable coupling. Otherwise, the inflatable device  
24 28 and the expansion cone 16 are substantially the  
25 same as the previous embodiments.  
26

27 The inflatable device 28 is inflated to expand the  
28 inflatable annular balloon-type portion. As the  
29 balloon-type portion expands, it contacts the tubular  
30 12, thus providing an anchor between the tubular 12  
31 and the casing 14. This contact between the balloon-

1 type portion and the casing 14 provides an anchor  
2 point and/or a seal between the tubular 12 and the  
3 casing 14. The seal is thus used to provide a sealed  
4 fluid chamber for movement of the apparatus 10.

5  
6 It should be noted that in this embodiment, the  
7 forces applied to the tubular 12 by subsequent  
8 movement of it, that is by pushing or pulling on the  
9 tubular 12 for example, will be transferred to the  
10 casing 14 via the inflatable device 28. However,  
11 unlike conventional slips, the inflated balloon-type  
12 portion is less likely to damage the casing 14.  
13 Additionally, the size of the balloon-type portion  
14 can be chosen whereby it is sufficiently large so as  
15 not to lose its grip on the casing 14, even when the  
16 inflatable device 28 is moved upwardly or downwardly.

17  
18 As the expansion cone 16 moves downwards through the  
19 tubular 12 to expand it, the movement thereof is  
20 stopped after a predetermined time or distance, at  
21 which point the expansion cone 16 is raised until the  
22 coupling between the expansion cone 16 and the  
23 inflatable device 28 latches. As with the previous  
24 embodiment, the inflatable balloon-type portion can  
25 be automatically deflated and further downward  
26 movement of the expansion cone 16 causes the  
27 inflatable device 28 also to move downward therewith.  
28 It should be noted that the downward movement of the  
29 expansion cone 16 should only be stopped once a  
30 sufficient length of tubular 12 has been expanded to  
31 provide a sufficient anchor.

1  
2 The inflatable device 28 is not essential as a seal  
3 is created at the surface by the rams of a blow-out  
4 preventer (BOP) closing over the drill pipe,  
5 electrical cable or umbilical to provide a fluid  
6 chamber above the cone 16. However, a local seal can  
7 be provided (e.g. the inflatable device 28).

8  
9 Referring now to Fig. 2, there is shown the apparatus  
10 10 in-use. It will be noted that the inflatable  
11 device has been inflated to fully expand the pre-  
12 expanded portion 12e into contact with the casing 14.  
13 The pre-expanded portion 12e is typically provided  
14 with a friction and/or sealing material (e.g.  
15 materials 100, 122 in Figs 3 and 4) so that a seal  
16 and/or anchor is created between the tubular 12 and  
17 the casing 14.

18  
19 The pump 18 draws fluid from below the cone 16 to  
20 above it (as indicated by arrow 22), and the pressure  
21 differential across the cone 16 causes it to move  
22 downward and thereby radially expand the tubular 12.

23  
24 It will be appreciated that the turbine 24 can be  
25 integral with the cone 16, or can be provided above  
26 or below it to draw fluids from above or below the  
27 cone 16 by way of the pump 18.

28  
29 The apparatus 10 has the advantage that it avoids  
30 "squeeze" problems. Conventional top-down methods  
31 are generally hydraulic where fluid is pumped onto an

1 upper face of the cone at pressure, forcing the cone  
2 to move downwards through the tubular to expand it.  
3 However, this causes the formation or payzone to be  
4 squeezed where movement of the cone downwardly in the  
5 conventional method forces the fluids therebelow back  
6 into the formation or payzone. This is because a  
7 borehole is typically a blind bore (i.e. it is closed  
8 at an end thereof that is typically near the  
9 formation or payzone). The fluids are thus forced  
10 into the formation or payzone and can cause  
11 significant damage and can possibly fracture the  
12 formation. The break up of the formation can  
13 seriously affect productivity therefrom and is thus  
14 undesirable.

15  
16 The squeeze effect can also cause the cone to stop  
17 because the fluids below the cone may become trapped  
18 and thus a build up of pressure would occur beneath  
19 the cone. As the pressure below the cone increases,  
20 the hydraulic pressure above the cone that drives it  
21 through the tubular must also be increased.

22  
23 However, the apparatus 10 draws fluids from below the  
24 cone 16 to above it and thus avoids the squeeze  
25 problems by removing the fluid below the cone. This  
26 is a significant advantage of the present invention.

27  
28 It will be appreciated that the pressure differential  
29 across the cone 16 may be quite large, and will  
30 generally be sufficient to start expansion (i.e.  
31 provide sufficient force to move the expansion cone



1 16 downwards and thus expand the tubular 12).  
2 However, the reduction on pressure below the cone 16  
3 is preferably kept to a minimum and will thus be  
4 relatively small. This is because it is undesirable  
5 for the pump 18 to draw up too much fluid because it  
6 is undesirable to draw fluids and sand etc from the  
7 formation or payzone.

8  
9 Embodiments of the present invention thus provide  
10 advantages in that there is provided a method of  
11 expanding a tubular that works from the top down.  
12 This has advantages in that if the apparatus 10  
13 becomes stuck due to restrictions or protrusions in  
14 its path, it is relatively simple to retrieve the  
15 apparatus 10 from the borehole. This is because the  
16 unexpanded portion of the tubular 12 is generally  
17 below the apparatus 10, and thus the restricted  
18 diameter of the unexpanded tubular does not make it  
19 difficult to pull the apparatus 10 out of the  
20 borehole.

21  
22 Also, embodiments of the apparatus 10 draw fluids  
23 from below the cone 16 to above it, and thus avoid  
24 squeezing the formation or payzone, thus providing  
25 significant advantages over conventional top-down  
26 expansion methods.

27  
28 Embodiments of the present invention also provide  
29 advantages in that less equipment is required. There  
30 is also no requirement to have a blind bore.

31

- 1 Modifications and improvements may be made to the
- 2 foregoing without departing from the scope of the
- 3 present invention.

1     CLAIMS

2

3     1.   Apparatus for radially expanding a tubular  
4     member, the apparatus (10, 200) comprising an  
5     expander device (16, 216) and a drive means (18, 24,  
6     218) for the expander device (16, 216), the drive  
7     means (18, 24, 218) being capable of moving with the  
8     expander device (16, 216).

9

10    2.   Apparatus according claim 1, wherein the drive  
11    means (18, 24, 218) is attached to the expander  
12    device (16, 216).

13

14    3.   Apparatus according to any preceding claim,  
15    wherein the drive means (218) is integral with the  
16    expander device (216).

17

18    4.   Apparatus according to claim 3, wherein the  
19    expander device (216) is provided with a  
20    longitudinal throughbore (217) in which the drive  
21    means (218) is located.

22

23    5.   Apparatus according to any preceding claim,  
24    wherein the drive means comprises a pump (18, 218).

25

26    6.   Apparatus according to claim 5, wherein the  
27    pump (18, 218) creates a differential pressure  
28    across the expansion cone (16, 216).

29

30    7.   Apparatus for radially expanding a tubular  
31    member, the apparatus comprising an expander device  
32    (16, 216) and a drive means (18, 24, 218) for the

1 expander device (16, 216), the drive means (18, 24,  
2 218) being capable of entering the tubular member  
3 (12) and moving the expander device (16, 216).  
4

5 8. Apparatus according to claim 7, wherein the  
6 drive means (18, 24, 218) is attached to the  
7 expander device (16, 216).  
8

9 9. Apparatus according to claim 7 or claim 8,  
10 wherein the drive means (218) is integral with the  
11 expansion cone (216).  
12

13 10. Apparatus according to claim 9, wherein the  
14 expansion cone (216) is provided with a longitudinal  
15 throughbore (217) in which the drive means (218) is  
16 located.  
17

18 11. Apparatus according to any one of claims 7 to  
19 10, wherein the drive means comprises a pump (18,  
20 218).  
21

22 12. Apparatus according to claim 11, wherein the  
23 pump (18, 218) creates a differential pressure  
24 across the expansion cone (16, 216).  
25

26 13. Apparatus for expanding a tubular member,  
27 comprising an expander device (216) having an  
28 integral drive means (218) for moving the device  
29 (216) within the tubular member (12).  
30

31 14. Apparatus according to claim 13, wherein the  
32 expander device (216) is provided with a

1 longitudinal throughbore (217) in which the drive  
2 means (218) is located.

3

4 15. Apparatus according to claim 13 or claim 14,  
5 wherein the drive means comprises a pump (218).

6

7 16. Apparatus according to claim 15, wherein the  
8 pump (218) creates a differential pressure across  
9 the expander device (216).

10

11 17. A method of radially expanding a tubular  
12 member, the method comprising the steps of providing  
13 an expander device (16, 216) and a drive means (18,  
14 24, 218), locating the device (16, 216) and drive  
15 means (18, 24, 218) in the tubular member (12), and  
16 actuating the drive means (18, 24, 218) to radially  
17 expand the member (12).

18

19 18. A method according to claim 17, wherein the  
20 method includes the additional step of locating the  
21 tubular member (12) in a second conduit (14).

22

23 19. A method according to claim 17 or claim 18,  
24 wherein the method includes the additional step of  
25 temporarily anchoring an end of the tubular member  
26 (12).

27

28 20. A method according to any one of claims 17 to  
29 19, wherein the drive means comprises a pump (18,  
30 218).

31

1 21. A method according to claim 20, wherein the  
2 step of actuating the drive means comprises applying  
3 power to the pump (18, 218).  
4

5 22. A method according to any one of claims 17 to  
6 21, wherein the method includes the additional step  
7 of attaching the drive means (18, 24, 218) to the  
8 expansion cone (16, 216).  
9

10 23. A method according to any one of claims 17 to  
11 22, wherein the method includes the additional step  
12 of providing the drive means (218) integral with the  
13 expander device (216).  
14

15 24. A method according to any one of claims 17 to  
16 23, wherein the method includes the additional step  
17 of creating a differential pressure across the  
18 expander device (16, 216).  
19

20 25. A method according to claim 24, wherein the  
21 method includes the additional step of drawing fluid  
22 from one side of the expansion cone (16, 216) to the  
23 other.  
24

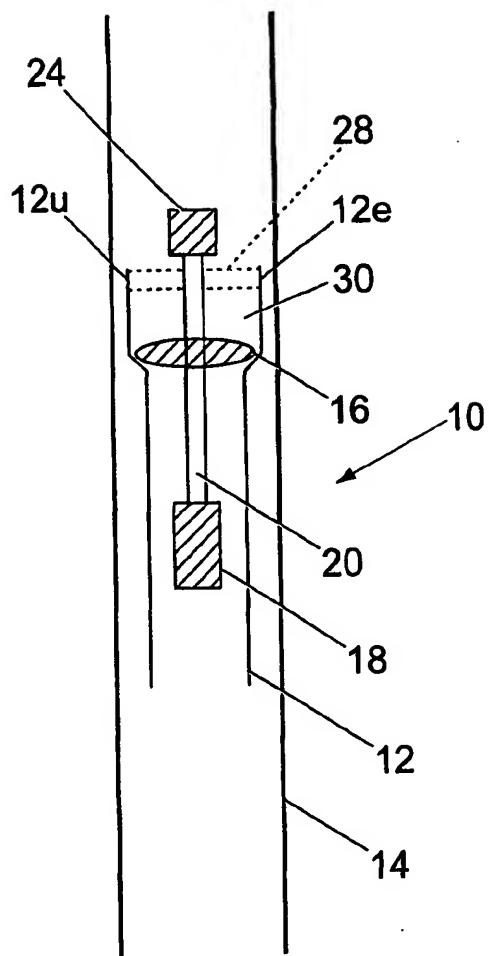


Fig. 1

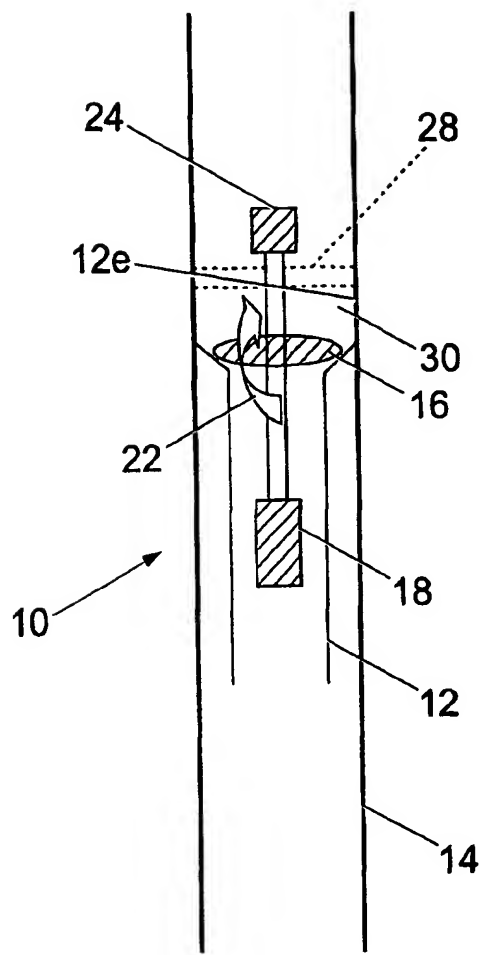
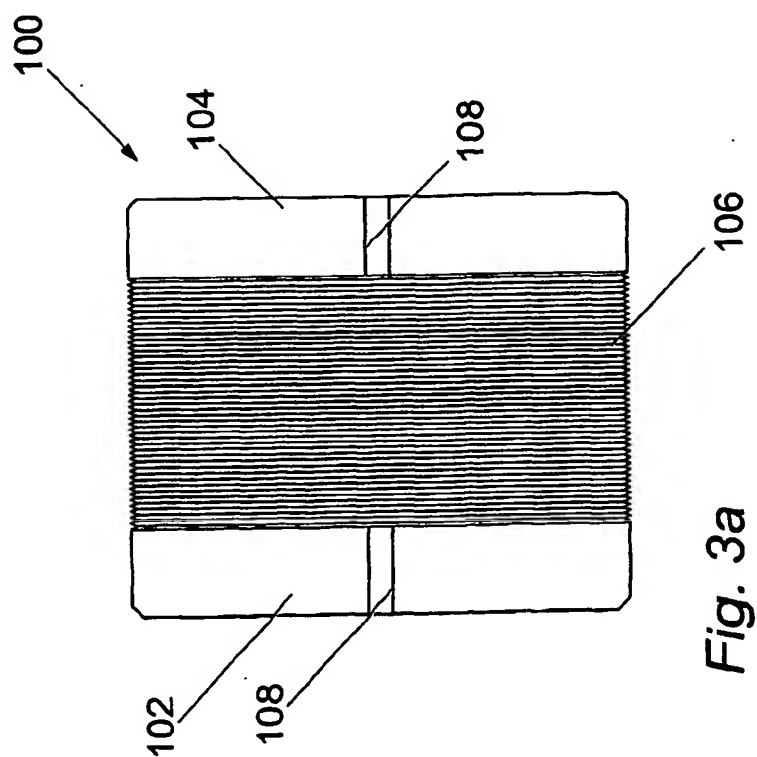
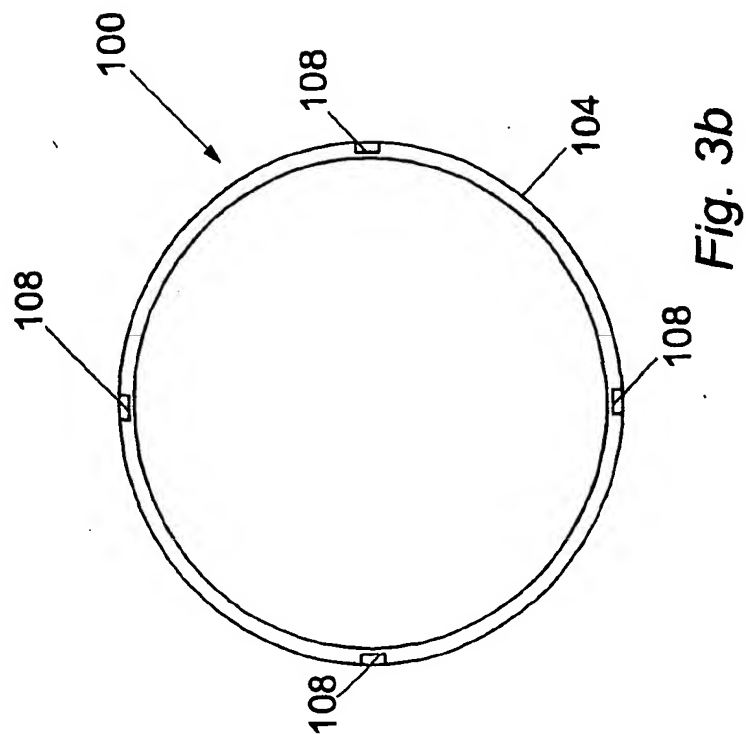
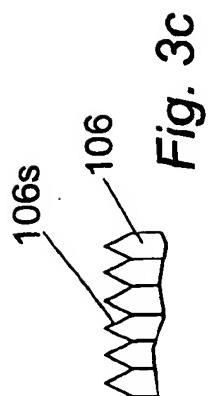


Fig. 2

2 / 4





3 / 4

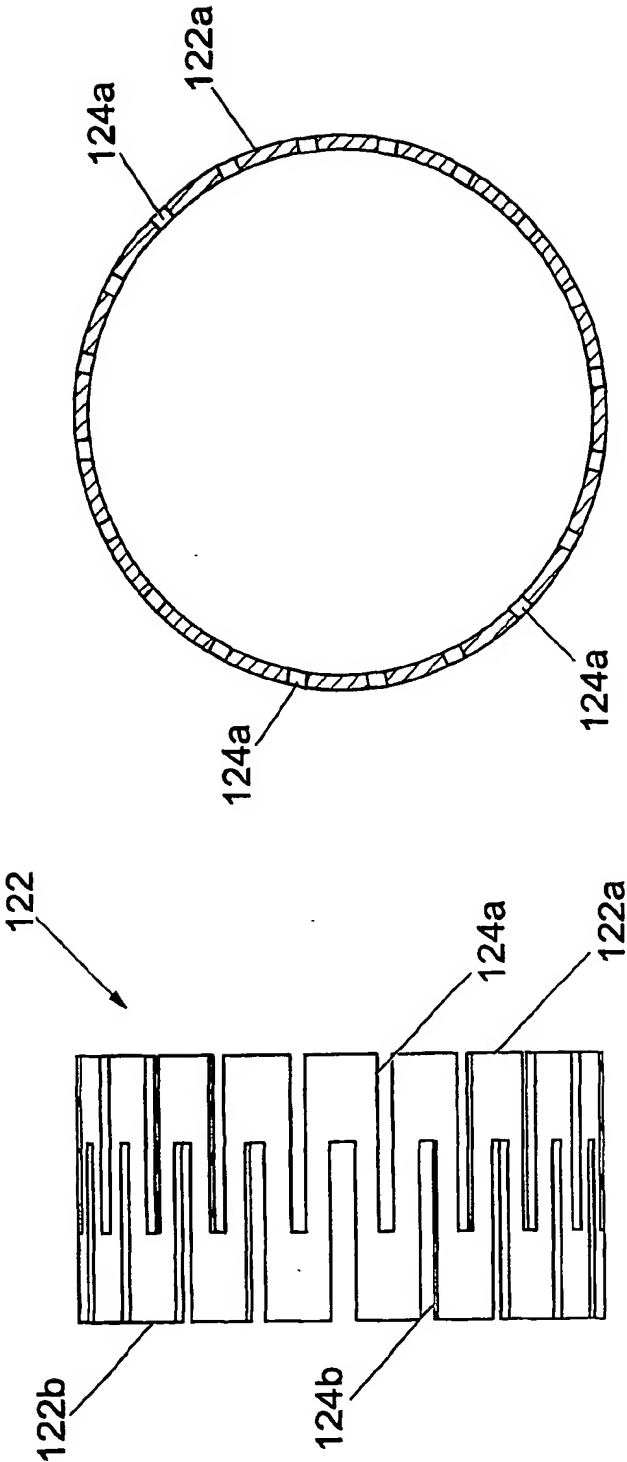
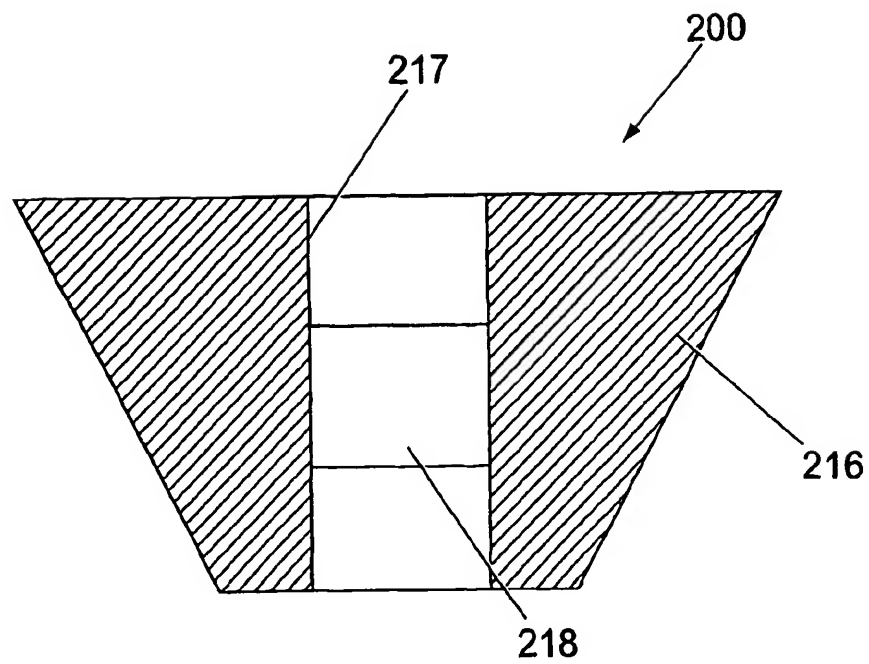


Fig. 4b

Fig. 4a

4 / 4



*Fig. 5*

# INTERNATIONAL SEARCH REPORT

International Application No.  
PCT/GB 02/02171

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 E21B43/10 E21B4/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 203 483 A (VINCENT RENIC P) 31 August 1965 (1965-08-31) column 5, line 45 -column 7, line 4; figures 7-10	1-25
X	WO 00 37766 A (ASTEC DEV LTD ;SIMPSON NEIL ANDREW ABERCROMBI (GB)) 29 June 2000 (2000-06-29) page 26, line 17 -page 27, line 9; figure 19 page 34, line 20 -page 38, line 12; claim 28; figures 27-30	1-5, 7-11, 13-25
P,X	WO 01 33037 A (STEWART R BRUCE ;COOK ROBERT LANCE (US); COWAN KENNETH MICHAEL (US) 10 May 2001 (2001-05-10) page 34, line 24 -page 36, line 18; figure 3	1-25
-/-		

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents:

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- \*Z\* document member of the same patent family

Date of the actual completion of the international search

6 August 2002

Date of mailing of the international search report

14/08/2002

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

van Berlo, A

## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/GB 02/02171

C(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	US 2001/045284 A1 (SIMPSON NEIL A A ET AL) 29 November 2001 (2001-11-29)  figures 6-8 ----	1-5, 7-11, 13-16, 18-23
A	WO 01 18355 A (DUCASSE CHRISTOPHER ;E2TECH LTD (GB); OOSTERLING PETER (NL)) 15 March 2001 (2001-03-15) page 10, line 23 -page 11, line 26 ----	1,7,13, 17
A	US 3 245 471 A (HOWARD GEORGE C) 12 April 1966 (1966-04-12) column 5, line 29-64; figures 1,2 ----	1
A	WO 99 35368 A (SHELL CANADA LTD ;SHELL INT RESEARCH (NL)) 15 July 1999 (1999-07-15) figure 4 -----	1

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No  
PCT/GB 02/02171

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 3203483	A	31-08-1965	US 3179168 A US 3203451 A	20-04-1965 31-08-1965
WO 0037766	A	29-06-2000	AU 1867900 A AU 1868700 A AU 1868800 A AU 1868900 A AU 1876600 A AU 1876800 A EP 1147287 A2 EP 1141517 A1 EP 1141515 A1 EP 1144802 A2 EP 1151180 A1 EP 1141518 A1 WO 0037766 A2 WO 0037771 A1 WO 0037768 A1 WO 0037767 A2 WO 0037772 A1 WO 0037773 A1 GB 2345308 A GB 2346632 A GB 2346400 A GB 2346909 A GB 2347445 A NO 20012596 A NO 20012597 A NO 20012598 A NO 20012599 A NO 20012600 A NO 20012865 A US 2002079106 A1 US 2002060079 A1	12-07-2000 12-07-2000 12-07-2000 12-07-2000 12-07-2000 12-07-2000 24-10-2001 10-10-2001 10-10-2001 17-10-2001 07-11-2001 10-10-2001 29-06-2000 29-06-2000 29-06-2000 29-06-2000 29-06-2000 29-06-2000 05-07-2000 16-08-2000 09-08-2000 23-08-2000 06-09-2000 27-07-2001 27-07-2001 30-07-2001 30-07-2001 30-07-2001 07-08-2001 27-06-2002 23-05-2002
WO 0133037	A	10-05-2001	AU 1356601 A WO 0133037 A1	14-05-2001 10-05-2001
US 2001045284	A1	29-11-2001	US 6325148 B1 US 2002079100 A1 AU 1044201 A WO 0146551 A1	04-12-2001 27-06-2002 03-07-2001 28-06-2001
WO 0118355	A	15-03-2001	AU 7021100 A EP 1210503 A1 WO 0118355 A1 NO 20021082 A	10-04-2001 05-06-2002 15-03-2001 13-03-2002
US 3245471	A	12-04-1966	NONE	
WO 9935368	A	15-07-1999	AU 740213 B2 AU 2418699 A BR 9814563 A CA 2316978 A1 WO 9935368 A1 EP 1044316 A1 JP 2002500306 T NO 20003402 A	01-11-2001 26-07-1999 17-10-2000 15-07-1999 15-07-1999 18-10-2000 08-01-2002 25-08-2000

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☒ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☐ **FADED TEXT OR DRAWING**
- ☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☐ **LINE(S) OR MARK(S) ON ORIGINAL DOCUMENT**
- ☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**